THE CLOUDSAT MISSION

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1. INTRODUCTION

In April 1999, NASA announced the selection of the CloudSat mission as an element of the Earth System Science Pathfinder (ESSP) Program. This mission, developed under the leadership of Professor Graeme Stephens of Colorado State University, is designed to investigate how clouds affect climate and to improve weather-prediction models. CloudSat will be the first spaceborne deployment of a 94 GHz cloud radar and will provide the first quantitative, global description of vertical cloud radiative properties. The spacecraft will be launched in March 2003 and will fly in formation on-orbit with the PICASSO-CENA spacecraft, that carries a three-channel backscatter lidar. Nearly simultaneous and closely located radar and lidar observations, complemented by high-spectral-resolution Oxygen A-band measurements and observations from the EOS-PM (TERRA) spacecraft will produce a robust data set for cloud and radiation studies.

CloudSat is an international mission, made possible by partnerships and contributions from the Canadian Space Agency, the U.S. Air Force, the Communications Research Laboratory of Japan, the U.S. Department of Energy, and research institutions in the USA, Japan, Canada and Europe.

THE CLOUDSAT PAYLOAD

The CloudSat spacecraft will carry a nadir-viewing 94-GHz cloud profiling radar (CPR) with a profiling A-band spectrometer/visible imager (PABSI).

The CPR will map vertical cloud profiles with sensitivity ε –28dBZ, 500 meter vertical resolution (250 m sampling) and a instantaneous horizontal footprint diameter of approximately 1.4-km.

The 94 GHz radar flight system development is a partnership between the Canadian Space Agency and the Jet Propulsion Laboratory. Active remote sensing of clouds requires technological developments that are underway in Canadian industry. Canada has the unique capability for 94 GHz Extended Interaction Klystron (EIK) technology and a well-recognized capability in mm-wave RF technology. The Canadian Space Agency will provide the 94GHz EIK flight models and the RF Electronics Subsystem for the CloudSat Mission. Development of an engineering model of the 94 GHz EIK was co-funded by the Communication Research Laboratory in Japan and JPL and was tested to launch vibration levels in the Spring of 1999. The second EIK engineering model will be thermal/vacuum tested in early 2000. Tests on the life-limiting cathodes indicate a 94% probability of achieving 2-year mission lifetime with a single EIK and a 99.64% with redundant EIKs ; the redundant approach is adopted by the CloudSat radar.

The PABSI instrument is comprised of a spectrometer and an imager. The spectrometer covers the spectral range 759-771 nm at a resolution of 0.03 nm or better. At a minimum, three adjacent, cross-track footprints will be used to guarantee overlap with the radar footprint. The PABSI imager has two bands at 748 ± 5nm and 760.7 ± 0.9 nm and images a crosstrack swath of 15 km at higher spatial resolution than the spectrometer to investigate the extent of homogeneity of the cloud field in which the radar and spectrometer footprints are imbedded. PABSI is sensitive enough to detect very thin clouds and, when combined with radar information, will improve the retrieval of cloud physical and optical properties as well as image the regional cloud field.

FORMATION FLYING

A combination of lidar data with the 94 GHz CloudSat radar data provides significant improvements in our abilities to determine cloud parameters. The CloudSat spacecraft will be launched with, and will fly in tight formation on-orbit with, the NASA PICASSO-CENA spacecraft (http://www-picasscena.larc.nasa.gov/picasso.html) that carries a backscatter cloud and aerosol lidar. Both spacecraft also fly in a loose formation with the NASA/EOS-PM (Aqua) satellite (Fig. 1 and Fig. 2).

Formation flying is a navigational strategy where the separation and relative motions of two spacecraft are controlled to preserve a pre-specified geometry. CloudSat will be responsible for implementing the spacecraft maneuvers required to maintain the formation.For scientific reasons, it is desirable that the average along-track separation between the CloudSat spacecarft and PICASSO-CENA spacecraft be made as small as practical, so as to be near-simultaneous. At this point in the design process, this separation will be no larger than 60 seconds (equivalent to 450 km spacecraft-to-spacecraft distance) with the goal to reduce this separation to 15 seconds if deemed achievable. Cross-track control amounts to maximizing the overlapping coverage by the radar and lidar footprints. This ultimately must be traded with the frequency of formation flying maneuvers necessary to maintain tight control on the cross-track motion (for example, motion related to differential drag). Based on preliminary analyses, and current estimates of the pointing capabilities of the two spacecraft and other instrument alignment factors, the cross-track distance between the radar and lidar footprints will never be more than 2km. Within this cross-track variation, direct overlap will occur a percentage of the time. Our goal is to achieve 50% direct overlap.

The CloudSat orbit is approximately circular at an altitude of 705 km. The inclination is very nearly sun-synchronous at 98.08 deg. The inclination is not exactly sun-synchronous so as to cause the orbit plane to precess slowly with respect to the EOS-PM orbit plane. This slow precession, coupled with the careful selection of the initial ascending node position, gives both CloudSat and Picasso-CENA the opportunity to make coincident radar/lidar measurements with the MODIS instrument on EOS-PM. Coincident observations at varying atmospheric look angles from MODIS will be possible over the course of the mission. The designated orbit inclination causes CloudSat to precess westward at 0.016 degrees per day with respect to EOS-PM's sun-synchronous orbit plane.

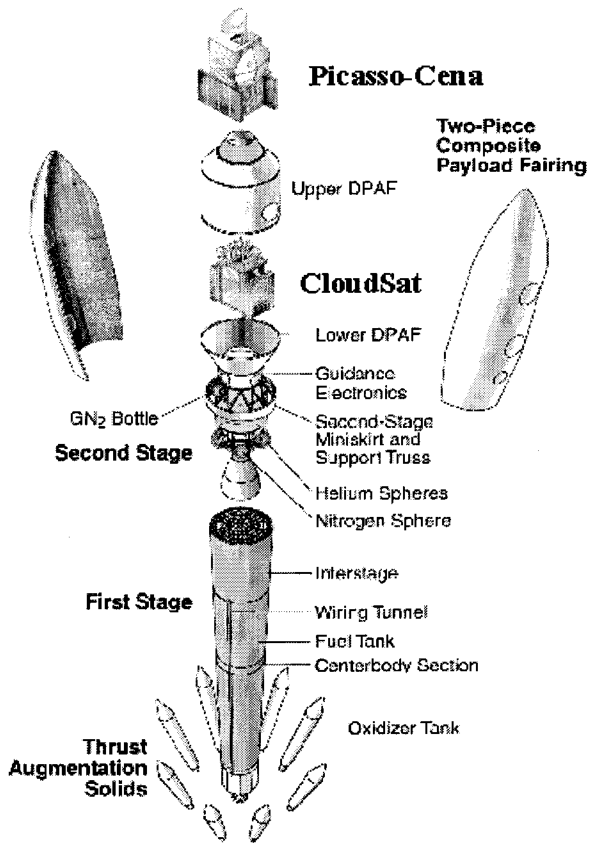

Fig. 1. CloudSat and Picasso-CENA will be launched together on a Delta-class launch vehicle in March 2003.

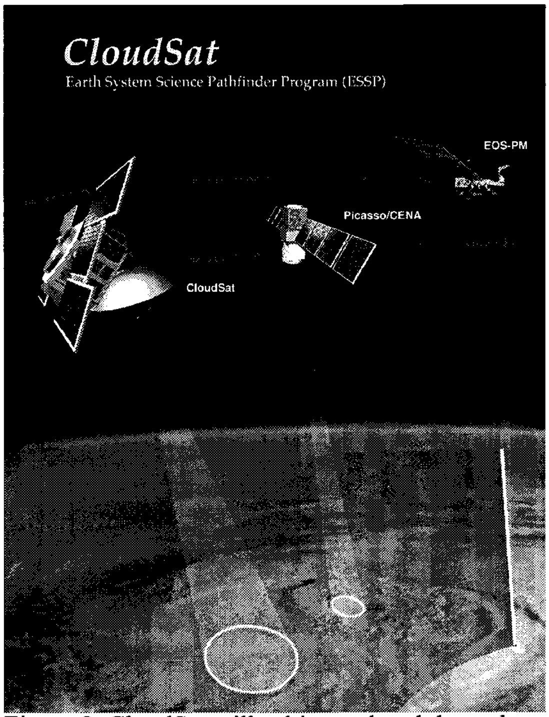

Figure 2. CloudSat will achieve a breakthrough in atmospheric sensing by flying in formation with PICASSO-CENA and EOS-PM.

MISSION OPERATIONS AND DATA PROCESSING

CloudSat will demonstrate the value of cloud radar observations to support operational weather analysis and forecasting, for civilian and military applications. For this reason, the U.S. Air Force Space Test Program is a partner in the CloudSat mission, providing flight operations, including mission planning, command generation, telemetry monitoring, spacecraft engineering, level 0 data processing. The Air Force Satellite Control Network (AFSCN) S-band antenna network will be used for all CloudSat ground antenna support.

Although multiple S-band links per day will be required to receive the science data, the advantage of multiple daily links is to present an opportunity to provide near-real-time radar data to the operational weather prediction centers. Two, one-week demonstration campaigns will provide ≥85% of the radar data within 3-6 hours of observation. Our goal is to find additional resources that would enable this timely delivery of radar data throughout the entire course of the mission.

CloudSat data processing will be conducted at the Colorado State University Cooperative Institute for Research in the Atmosphere (CIRA). CIRA will process and deliver standard and experimental data products, as well as the rapid turnaround radar data.

VALIDATION

CloudSat data products will be validated with the help of ground and airborne measurements, principally supplied by the U.S. Dept. of Energy's Atmospheric Radiation Measurements (ARM) Program, and supplemented with field campaigns supported by Japan, Canada, Germany, the USA and United Kingdom through the activities of the CloudSat extended Science Team.

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